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NOTE ON A NEW AND SIMPLE METHOD OF DEAD RECKONING IN AERIAL NAVIGATION.

By Louis Constantin.

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Let us take an airplane following a given geographical route OX (Fig. 1) at a ground-speed V.

When the airplane arrives at O, let us suppose that it gets into a lateral wind of speed and direction OW. When the forces of inertia are overcome, that is, in a very few minutes, the new route of the airplane will make an angle with the original route and the ground-speed will become, in magnitude and direction, OW', the vector VW' being equal, in magnitude and direction, to OW.

We also know that if we take the absolute value of

$$V\,W = V\,W'$$

the relative wind blowing on the airplane at the instant it entered the zone of lateral wind will be equal in magnitude and direction to the vector WO. $V_1 W$ will thus represent the increase, positive or negative, in the ground-speed of the airplane.

Consequently, if the airplane is provided with a speed indicator and a side slip indicator, the navigator will know the magnitude and direction of the new lateral wind, that is, the length OW and the angle ω.

By means of a simple trigonometric calculation he will deduce

* From "L'Aerophile," June 1-15, 1923, pp. 177-178.

from these the length of the vector WV and the angle WVO, that is, the speed and direction of the lateral wind. The triangle OVW' will then be completely determined and another simple calculation in trigonometry enable the navigator to know the magnitude and direction of the vector OW', that is, the new geographical route and the angle of drift. If the speed and side slip indicators are recording instruments the navigator will be able to correct for drift every half hour, for instance.

This method, though very simple in theory, would be rather irksome in practice. Fortunately it can be transformed and simplified.

Let us suppose that the pilot always endeavors to place the axis of his airplane parallel to the relative wind.

In the case we are considering, he will turn the airplane to the left by an angle ω; this means that when the forces of inertia are overcome, the new geographical route will be in the direction OU' and with a ground-speed equal to the length of the vector OU'. In "L'Air" for April 15, 1923, I have shown that the pilot will have plenty of time for this maneuver.

The error of direction is thus η' instead of ω', and the figure shows that the fact of keeping the airplane parallel to the relative wind diminishes drift automatically and to a considerable degree. Later, we will estimate more closely the value of η'.

For a complete correction we should have had to turn the axis of the airplane by an angle $\omega + \eta$ (Fig. 1). The ground-speed would then have been OU.

Let us find the value of the angle η and the speed OU.

We first remark that the quadrilaterals V_1V_2UU', WV_2UV, $WV_1U'V$, are, all three, parallelograms. Therefore, the triangle VWV_1 is equal to the triangle UVU', and the angle V_2WV_1 is equal to the angle UVU' and to ω.

On the other hand, when ω is not more than 5°, the lengths WV_1 and WV_2 will not differ by more than 0.5%. Finally, the straight line V_2V_1 forming at V_1 a tangent to the circle the center of which is O and the radius OV, it is perfectly legitimate from a practical point of view to consider this straight line V_2V_1 as a perpendicular to the line WO. If in the same manner we assimilate the angles ω and η to their tangents, we see that we have the relation:

$$\eta = \omega \frac{WV_1}{OV_1}$$

Now OV_1 is the soeed V and V_1W is the increase of speed due to the lateral wind. Thus, instead of turning his airplane only at an angle ω, the pilot will turn it at this angle plus a fraction equal to the increase of the original speed, and the speed indicator will tell him just what this increase amounts to.

For instance, if the side slip indicator marks an angle of 5° and the speed indicator an increase of speed of 10%, the correct maneuver would be to turn the airplane at an angle of 5.5°. Thus the correction will be scrupulously exact.

But we see that this angle η will usually be very small. In that case, the corresponding correction may be neglected, the error of direction in that case being:

$$\eta' = \omega \frac{WV_1}{OV_1 - WV_1}$$

that is, practically scarcely larger than η, or, in the above example, of the order of half a degree.

The ground-speed OU is equal to:

$$OU = V - WV_1$$

In order to obtain this speed the pilot must thus deduct from his speed V the increase marked on the speed indicator.

Of course, if the increase WV_1 is negative, the corresponding angle η must be deducted from the angle ω to give the complete angular correction and the absolute value of this increase must be added to V to give the new ground-speed.

If recording indicators are used the navigator will always have the necessary data for judging the conditions and making the additional corrections required.

Conclusion.

To sum up, with a side slip indicator the pilot will always know when the airplane is struck by a side wind. If he maneuvers so as to cancel the angle of drift, that is, if he maintains his slip indicator at O, the correction will probably be sufficiently approximate for all practical purposes.

A glance at the speed indicator will enable the pilot further:

1. To complete the correction if he wishes.

2. To estimate the increase or decrease of ground-speed due to

a lateral wind.

Finally, if the navigator has recording instruments he will be able to trace the route followed and make the complementary corrections whenever he desires to do so.

Remarks.

1.- In all we have said up to now, we have assumed that the airplane was travelling in a straight line.

There are, however, very sensitive turn indicators so that the pilot may be warned of the curvature of his line of flight.

In this case also it would be better to have a recording instrument. It would enable the navigator to reckon his line of flight with greater accuracy.

In "Rapports sur le Premier Congrès International de la Navigation Aérienne," Vol.II, p.94, I have shown how a good side slip indicator can be used as a turn indicator. It would be quite easy to fit a recording device to such an instrument.

2.- Probably no airplane could keep a perfectly straight line of flight, even in the absence of wind. For this to be possible the airplane would have to be perfectly symmetrical with respect to its longitudinal axis, which is difficult. Besides, there is the propeller torque to be considered and this can only be balanced by means of a certain dissymmetry.

In perfectly calm weather, all airplanes fly more or less sideways. This fact must, of course, always be taken into account.

The side slip indicator is very useful for this purpose.

3.- Unfortunately, dissymmetry may be produced during flight; for instance, if anything went wrong with the wing adjustment. This would be a very serious matter and would cause the same kind of inconveniences in dead reckoning, whatever the method employed. Still, the simultaneous observation of the revolution counter and side slip indicator immediately after a right about turn would give a capable pilot exact information as to the extent of the damage. He will make such a maneuver whenever he has reason to suspect serious trouble.

We cannot dwell longer here on the various methods to be employed. The subject will be taken up again later on, but any technician will be able to find a solution for the problem.

In a multi-engined airplane a change in the R.P.M. of one of the engines may also disturb the balance of parts.

Here again the examination of the revolution counter and side slip indicator will give the pilot all the indications necessary for estimating the error, particularly if he has had some experience in such work.

4.- The determination of the basic speed V is obviously of the greatest importance and it should be determined as accurately as possible, either by means of chronographs or by studying the speed of the airplane with reference to the air - given by the speed indicator - and at the same time studying the meteorological data obtainable on the velocity and direction of the wind at the corresponding altitude.

5.- It is evident that every increase of speed such as V_1W will correspond to upward or downward movements of the airplane. The pilot will therefore have to make longitudinal corrections as well as lateral and horizontal.

In a gusty wind he will therefore have a great deal to do and it would be to his advantage to keep at a high altitude where the wind is not so variable. He need not hesitate to do this, for with a good system of dead reckoning he runs very little risk of losing his bearings.

But that is not all.

In "L'Air" of April 15, in an article on "Bumps," I showed that three wind vanes sufficiently powerful, one acting directly on the elevator, another on the ailerons, and the third on the rudder, would invariably make the correct maneuver automatically, though the best of pilots would very often make a mistake.

There will then be no difference between the work of the pilot and that of the navigator - and everybody will agree that this is an ideal towards which we should all strive - and the geographical route will be kept automatically, at least to within very slight deviations which the navigator can correct at intervals.

6.- Lastly, it is certain that this method of dead reckoning should not be used to the exclusion of every other, at least until its efficiency has been confirmed by long experience.

For instance, a direct measurement of drift, when it can be made, will be a valuable means of checking the accuracy of the

successive integrations thus effected.

It is hardly necessary to add that the position of the airplane should be marked on the map whenever possible.

But it does seem that the suggested method would considerably diminish the uncertainty now prevailing in aerial navigation.

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Fig. 1